Nurse-Administered Ketamine Sedation in an Emergency Department in Rural Uganda


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Study objective: We determine whether, after a brief training program in procedural sedation, nurses can safely independently administer ketamine sedation in a resource-limited environment.

Methods: This is an observational case series of consecutive sedations performed in an emergency department in rural Uganda at approximately 5,000 feet above sea level. The data were collected prospectively in a quality assurance database. As part of a larger training program in emergency care at Karoli Lwanga Hospital in rural Uganda, nurses with no sedation experience were trained in procedural sedation with ketamine. All sedations were monitored by a nonphysician research assistant, who recorded ketamine dosing, duration of each procedure, adverse events, and nurse interventions for each adverse event. In accordance with standard definitions in the emergency medicine sedation literature, adverse events were defined a priori and classified as major (death, need for bag-valve-mask ventilation, or unanticipated admission to the hospital) or minor (hypoxia, vomiting, emergence reactions, hypersalivation). The primary statistical analysis was descriptive, with reporting of adverse event rates with 95% confidence intervals (CIs), using the nurse as the unit of analysis.

Results: There were a total of 191 administrations by 6 nurses during the study period (December 2009 through March 2010). Overall, there was an 18% adverse event rate (95% CI 7% to 30%), which is similar to the rate reported in resource-rich countries. These events included hypoxia (22 cases; 12%), vomiting (9 cases; 5%), and emergence reaction (7 cases; 4%). All adverse events met our a priori defined criteria for minor events, with a 0% incidence of major events (1-sided 97.5% CI with the nurse as unit of analysis 0% to 46%). The procedural success rate was 99%. Sedation was practitioner rated as “excellent” in 91% of cases (95% CI 86% to 94%) and “good” in 9% (95% CI 6% to 14%). Patients reported they would want ketamine for a future procedure in 98% of cases (95% CI 95% to 100%).

Conclusion: In resource-limited settings, nurse-administered ketamine sedation appears to be safe and effective. A brief procedural sedation training program, coupled with a comprehensive training program in emergency care, can increase access to appropriate and safe sedation for patients in resource-limited settings. [Ann Emerg Med. 2012;59:268-275.]

Please see page 269 for the Editor’s Capsule Summary of this article.

INTRODUCTION

Background

Throughout many low- and middle-income countries, there is a shortage of medical providers, especially in rural areas.

Patients may experience delays in care or be unable to receive proper care because of the absence of skilled providers, which results in unnecessary morbidity and mortality, especially in emergency situations. Nurses are generally more plentiful in low- and middle-income countries compared with physicians or midlevel providers. Thus, a policy of “task shifting” is being promoted in these settings to help fill the void in services. Task shifting involves delegating tasks that were originally only in the...
emergency care. The goal of the program was to train nurses to independently assess and treat patients with emergent conditions. This training included education on how to carry out procedures necessary for proper emergency care.

Given the large number of painful procedures performed in this setting and the limited anesthetist resources, training in procedural sedation was undertaken. Agents available for procedural sedation at the hospital include diazepam, meperidine, thiopental, and ketamine. Ketamine has been used widely in resource-limited settings and has an excellent safety profile. Therefore, it was selected as the agent of choice for ED procedural sedation in patients of all ages.

**Goals of This Investigation**

To our knowledge, this is the first published report of training nonanesthetist nurses in procedural sedation techniques in resource-limited settings. As a result, a quality assurance database was created to ensure that the use of ketamine by these providers was safe and effective. The specific aim of this study was to query the database to determine the safety and effectiveness of ketamine administration by trained nurses in a resource-limited ED in a developing country.

**MATERIALS AND METHODS**

**Theoretical Model of the Problem**

As part of a comprehensive nurse-training program in emergency care at a Ugandan district hospital, 6 nurse participants were trained in the use of ketamine sedation. Basic nursing education in Uganda involves a 2.5-year training program that includes clinical rotations on various wards, supplemented with basic didactics. The curriculum covers basic anatomy, pharmacology, pathophysiology, and medical ethics. There is no training in basic life support, airway management, anesthetic techniques, or advanced procedural skills. Entrance requirements are similar to those of licensed practical nurse programs in the United States. Students graduating from the training are considered enrolled nurses. Additional training (1.5 years) can be pursued, leading to a registration in nursing. This coursework focuses on more advanced anatomy, physiology, and pharmacology principles, as well as some leadership training. This curriculum, however, still does not include basic life support, anesthetic techniques, or advanced procedural skills.

The nurse volunteers for the sedation training were concurrent trainees in a more comprehensive emergency care training program. One participant in these training programs was a registered nurse with approximately 20 years of experience. Three participants were enrolled nurses with 2 years of experience, and the remaining 2 were enrolled nurses who had graduated from nursing school just before beginning the training program. The registered nurse had 1 year of experience working in the hospital’s ED, and 1 of the enrolled nurses had 6 months of experience in the ED before onset of the training. None of the nurses were certified in basic cardiac life support,
had experience with airway management, or had administered ketamine before the onset of the training. All nurse volunteers for the program successfully completed the requirements for certification and participated in the study.

The sedation certification program consisted of a 1-hour lecture, provided by a board-certified emergency physician, that reviewed the pharmacology of ketamine, respiratory physiology and pathophysiology, principles of procedural sedation, advanced airway assessment, and bag-valve-mask ventilation skills. Additionally, the nurses received an extensive written curriculum that reviewed the above topics in more detail. Each nurse was then required to log at least 10 sedations that were directly supervised by an emergency medicine senior resident (ie, in the final year of training and with significant sedation experience) or board-certified emergency medicine attending physician. Finally, the nurse candidates were administered a 15-item written short-answer examination. After completing all of these steps and passing the test, the nurse was allowed to sedate patients without physician supervision.

A ketamine protocol was developed (Figure). According to the protocol, all patients were to be monitored with pulse oximetry and administered supplemental oxygen by oxygen concentrator if possible (supplemental oxygen is occasionally unavailable at the study site). Each sedation required a dedicated trained nurse operator to perform the sedation and an additional provider to perform the procedure for which the patient was being sedated. The protocol allowed for ketamine to be given either intramuscularly or intravenously over 60 seconds, as in the Figure. No maximum single dose, nor maximum number of doses was set. Atropine and diazepam were not routine adjuncts to sedation; these agents were administered only at the discretion of the treating nurse in response to an emergence reaction or hypersalivation. Because of the lack of more desirable alternatives to ketamine in the study system, the protocol did not exclude any patients according to age (young or elderly). Only patients with significant active upper respiratory symptoms were not eligible to receive ketamine.

**Study Design**

This was a consecutive observational case series of prospectively collected data from a quality assurance database. Because none of the nurses had experience with ketamine administration and there was no existing program from which the training could be modeled, a quality assurance database was created by research assistants trained by the American Board of Emergency Medicine–certified emergency medicine specialist working at the site. The research assistants were instructed on how to measure respiratory rate, interpret pulse oximetry values, and recognize different interventions (head repositioning, jaw thrust, chin lift, bag-valve-mask ventilation, increasing oxygen flow, and tactile stimulation) that nurses should perform in the event of respiratory deterioration. Before participating in case observation and data collection, the research assistants were required to observe emergency physician–supervised sedations and note adverse events and provider interventions. Adverse events of laryngospasm, desaturation, apnea, emergence reactions, and hypersalivation were defined a priori, and explicit criteria for their diagnosis were explained to the research assistants. The definitions used were consistent with current emergency medicine literature. All data forms were filled out by the research assistants in real time and then entered into the computerized database with Excel 97-2000 (Microsoft, Redmond, WA).

The database included demographic information, relevant medical history, type of procedure, ketamine dose, route of administration, required number of doses, occurrence of adverse events (apnea, laryngospasm, need for bag-valve-mask ventilation, desaturation, vomiting, and emergence reactions), procedural success, nurse satisfaction, patient satisfaction, and whether the patient would want sedation again for a similar procedure. The database included all consecutive nurse-performed procedural sedations. This review of the database was approved by the Hospital Management Team of Karoli Lwanga Hospital and was approved under exempt status by the University of Oklahoma institutional review board.

**Setting**

All sedations occurred at Karoli Lwanga Hospital and were performed independently by nurses undergoing the training program in emergency care. The majority of sedations occurred in the ED. However, given the limited anesthetist resources, a few of the sedations were performed on the inpatient ward if a
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patient required a procedure and could not be moved to the ED (eg, application of femoral traction in a child). These sedations were performed independently by the same nurses (who had undergone the study-related training) and were observed by the same research assistant, as per the above ED ketamine protocol; therefore, these “non-ED” sedations were included in this analysis. Physicians did not supervise or participate in the sedation management for any sedation in the database. Because the data collection occurred concurrently with the larger training program in emergency care, emergency physicians were sometimes at the bedside supervising the nurse performing the procedure that required sedation. The emergency physicians did not supervise the sedation, advise the sedating nurse on medication dosing, or otherwise participate in sedation management. There was no requirement for an emergency physician to be present, and if the nurses had achieved competency in the procedure requiring sedation, there were no emergency physicians present during procedures. The research assistant recorded any cross-management of the sedation by a physician involved in supervising the procedure that necessitated sedation.

Selection of Participants

The ketamine training program was instituted in September 2009. The actual initial-procedure start date varied for the individual nurses because they had to first complete the required training. Sedations in this study were performed between December 2009 and March 2010. Once each nurse completed the training and passed the test, all future sedations performed by that nurse were entered into the database; in this sense, the data set is a consecutive sampling of all sedations performed by each certified nurse. Any sedation performed in the ED was eligible to be conducted by a nurse; there were no exclusions for American Society of Anesthesiologists class or age of the patient. The research coordinator (K.N.) and the lead investigator (M.B.) met daily to review sedations and discuss any potential adverse events.

Outcome Measures

The outcomes that were assessed were related to safety of the sedation program, as well as nurse and patient satisfaction with the sedation. Major and minor adverse events were defined a priori and are consistent with current recommendation from the emergency medicine sedation literature. We decided a priori to deviate from these recommendations in 2 instances. First, we did not use an intervention-based definition of hypoxia or apnea because the goal was to monitor nurse intervention to desaturating and using this definition could lead to underreporting of sedation adverse events if the nurses did not respond appropriately. Second, we included 2 additional major adverse events: need for bag-valve-mask ventilation and requirement for unanticipated hospitalization because of a sedation event. Bag-valve-mask ventilation was considered a major adverse event given the lack of available practitioners with advanced airway management skills in this setting. “Need for unanticipated admission to the hospital” was added as a surrogate marker for concern by the nurse performing the sedation that the patient had experienced an adverse event during the sedation.

Thus, major adverse events were defined as need for bag-valve-mask ventilation, unanticipated admission to the hospital, or death possibly related to sedation. Minor adverse events were defined as desaturation below 90% for greater than 10 seconds, apnea, vomiting, emergence reactions, and hypersalivation requiring suctioning. Any episodes of vomiting that occurred within 12 hours of the procedure were recorded as a minor adverse event.

After the sedation, the nurse performing the sedation was asked to rate sedation adequacy on a 4-category scale (inadequate, adequate, good, excellent). Patients were also queried about the experience and whether or not they would elect to have ketamine sedation again should they require a future similar procedure (yes/no). Patient queries were administered on postsedation day 1 for those who were inhospital and on postsedation day 3 (at routine follow-up for the larger emergency care training program) for those who had not been admitted. If the patient was below school age or had altered mental status, the accompanying family member was queried about satisfaction with the sedation if he or she was present during the procedure.

Primary Data Analysis

At the conclusion of the study, the database was deidentified and analysis was performed with Stata 12 MP (StataCorp, College Station, TX). The statistical methods to analyze this descriptive analysis were primarily descriptive, with generation of 95% binomial exact confidence intervals (CIs) (97.5% CIs at which point estimates were zero) around rates and proportions. Because the study’s continuous data were not distributed normally, these data were summarized with nonparametric techniques such as calculation of medians and interquartile ranges. Study results are presented with breakdown by the administering nurse as the unit of analysis. The number of nurse “clusters” being small (at 6), we chose to execute analysis by allocation unit, using inverse variance weighting to adjust for differences in cluster size.5

RESULTS

During the study, 192 sedations were eligible for inclusion. Once each nurse had completed the training, all consecutive sedations performed by that nurse were included. Thus, this data set represents all consecutive sedations performed by a nurse certified in our ketamine training program. One sedation was excluded because a visiting emergency physician thought that the patient’s injuries were too painful for the patient to be transferred to radiology without being sedated during the transfer. As a result, a large portion of this sedation could not be monitored. The patient had no complications from the sedation (as reported by the physician) at any point.

A total of 191 nurse-administered ketamine sedations were available for review, and 177 (92%) were available for follow-up
on postsedation day 1 or 3, as described in the “Materials and Methods.” These 191 sedations were performed on 118 patients (some patients had multiple sedations on different days, usually for wound care procedures). Each nurse performed roughly one sixth of the total sedations (Table 1). The patients ranged in age from 1 week to 78 years. Approximately 51% of the patients were younger than 18 years, and 18% were younger than 2 years. The primary indications for sedation are listed in Table 1. Meperidine or diazepam was administered within 1 hour of the sedation in approximately 10% of the encounters. It was local practice to use meperidine for analgesia for painful conditions. Diazepam was generally used in the event that the patient experienced an emergence reaction.

The duration of the sedation was recorded for 180 of the 191 sedations. The median procedure time was 20 minutes (range 2 to 195 minutes). In 172 sedations, ketamine was administered intravenously and in 19 sedations, intramuscularly. For sedations in which intravenous ketamine was used, patients required a median of 2 doses and 2 mg/kg (range 1 to 15 doses; 0.7 to 20 mg/kg). For intramuscular sedations, the median number of doses was 1 (range 1 to 12 doses) and the median dose was 5 mg/kg (range 1.1 to 11 mg/kg).

The intramuscular administration data were skewed by 2 outlier cases. The first was a 9-month-old child with burns who received only 1.1 mg/kg and tolerated the procedure well. It is not clear whether the sedating provider intended to administer this low of a dose or administered a lower dose because of an error calculating the appropriate dose, or whether the dose was recorded incorrectly on the initial procedure form. The second case was a trauma patient who received 11 mg/kg but received a total of 12 doses; this patient required extensive wound debridement but was combative and in shock. The remaining 17 patients who had intramuscular ketamine received between 3.8 and 8.9 mg/kg cumulative in 1 to 2 total doses.

There was an 18% rate of minor adverse events (95% CI 7% to 30%) (Table 2). There were 2 cases in which the pulse oximeter readings were thought to be inaccurate before, during, or after the procedure. The nurse performing the procedure verbalized this to the research assistant, who concurred with the assessment. These 2 patients underwent uneventful sedations without apnea and recovered uneventfully. The nurse leading each sedation promptly managed all adverse events, with the exception of 1 desaturation episode that lasted 17 seconds. In this case, the nadir SaO₂ was 87% and resolved spontaneously. The nurse was observed to be monitoring the patient closely but did not reposition the head or increase the flow of oxygen.

There were no major adverse events. The 1-sided 97.5% CI for major adverse events (using the nurse as unit of analysis) was 0% to 46%. Procedural success rates indicated a high quality of sedation. In the database, there were a total of 225 procedures performed on patients under ketamine sedation. Of these, 223 (99%) were completed successfully. There were no cases of failed procedures that the sedating nurse believed were due to inadequate sedation.

Nurses assessed the quality of the sedation as “excellent” in 91% (95% CI 85% to 94%) of cases and “good” in the remaining 9% (95% CI 6% to 14%). Data about patient

### Table 1. Indications for sedation.

<table>
<thead>
<tr>
<th>Procedure Requiring Sedation</th>
<th>Nurse</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abscess drainage</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>Burn wound care</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Unable to cooperate for procedure</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Ear, nose, throat foreign body</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Laceration repair</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Orthopedic procedure</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>Other wound care</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>30</td>
<td>32</td>
</tr>
</tbody>
</table>

### Table 2. Complication rates by staff.

<table>
<thead>
<tr>
<th>Adverse Event</th>
<th>Nurse</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergence</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Hypersalivation</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Hypoxemia</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Vomiting</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>13</td>
<td>6</td>
</tr>
</tbody>
</table>

| Patients with any adverse event* | 12 | 6 | 6 | 3 | 5 | 3 | 35 | 40% of 30 | 19% of 32 | 17% of 36 | 10% of 31 | 17% of 30 | 9% of 32 |

*Four patients had 2 complications; thus, there were 39 complications in 35 patients.
preference were available for 180 of the 191 episodes of sedation. Of these, 177 (98%; 95% CI 95% to 100%) patients reported during a postsedation interview that they would want the procedure conducted under ketamine again if the procedure needed to be repeated. Three patients (2%) reported that they would want a different agent to be used for a future sedation.

LIMITATIONS

Although this study is a review of a database, it does not have some of the limitations that typically affect such studies. The data were collected prospectively as part of a quality assurance program because there were no models on which to base this sedation training. The database was designed to assess the quality and safety of the nurse-administered sedations after our specific ketamine sedation training program. Although it is possible that some of the outcomes could be interpreted differently by other research assistants, 73.8% of the sedations were observed by the research coordinator (K.N.) and most of the outcomes are objective (eg, oxygen saturation, need for bag-valve-mask).

During the study, there was no access to end-tidal CO₂ monitoring equipment, and determination of apnea was left to the research assistants, who did not have advanced training in airway management. Therefore, it is possible that patients experienced subclinical apnea or respiratory depression that was not recorded in the database. This situation simulates actual practice because it is unlikely that ETCO₂ monitoring will be widely available in resource-limited settings. Additionally, by sedation consensus guidelines, if a patient experiences respiratory depression without clinical consequences, it would be considered insignificant. ³

The ketamine sedation training was a small part of a more comprehensive training program in emergency care. At the time of the study, the nurses were in the first year of this clinical training program. The program teaches the nurses a symptom-based approach to patient evaluation and management. The goal was to enable the nurses to be able to independently provide diagnoses for and manage patients presenting with undifferentiated urgent or emergent presentations of diseases common in this rural district hospital. Instruction on management of diseases was tailored to resources available in this setting in Uganda. Basic and advanced life support, as well as advanced airway management, was not a component of the training because ICU-level care is not available at the district hospital. It is probable that some of the emergency care training provided to the nurses, particularly assessment and management of critically ill patients, improved the ability of these nurses to perform procedural sedations safely. Given the concurrent nature of the training, it is not possible to determine the size of this effect, if one exists. These data cannot be generalized to providing sedation training outside of the scope of a broader training program in emergency care.

Finally, ketamine is a unique sedative agent and has a long history of safe use in resource-limited settings. The results of this study do not apply to the safety of other agents. The fact that one provider (the nurse) performed the sedation, whereas another nurse performed the procedure, represents both a similarity to US practice and a potential study limitation. The procedures requiring sedation were universally performed by one of the other nurses in the larger emergency care training program. In some instances, however, in which the trainee was not competent to perform the procedure independently, an emergency physician was present to supervise the nurse-trainee performing the procedure (but not the sedation). The research assistant monitoring the sedation was instructed to note any physician interference with, supervision of, or “cross-management” of the sedation. Other than the single case discussed above, which was excluded from the analysis, there were no instances of physician cross-management or interference with the nurse performing and managing the sedation. Thus, our data represent sedations in which the nurses managed the sedation completely independently. These were all consecutive sedations performed as described above. Therefore, the data suggest that properly trained nurses (ie, nonphysicians) can serve as the “sedating health care provider” in a resource-limited setting.

DISCUSSION

Ketamine is a phencyclidine derivative used for sedation and analgesia. It produces dissociation from the environment (eg, external sight, sound, and pain stimuli) by acting on the limbic system and the cortex. This unique property of ketamine enables it to produce amnesic, analgesic, and sedative effects. Patients have preserved respiratory drive and laryngeal reflexes while in the dissociated state. For these reasons, it has been widely used in resource-limited settings, in which monitoring equipment is not widely available. Guldner et al have even advocated its use in field environments by military medical teams. ⁷

In a survey of physicians from resource-limited countries, physician respondents reported using ketamine extensively. ⁴ A minority (39%) of these physicians simultaneously supervised the administration of ketamine and performed the procedure. ⁴ Only 10% of the physicians surveyed used pulse oximetry “often” or “always” during ketamine sedations, and only 45% reported any type of vital sign monitoring during the sedation. ⁴ Although this study is limited in that it relied on physician recall and self-reporting, the physicians surveyed reported a “low” risk of adverse events attributed to ketamine.

In high-income countries, there have been multiple reports in the past decade of nurses not trained as anesthetists performing procedural sedation in nonemergency settings, particularly during endoscopy. ⁸⁻¹⁰ These articles report large numbers of patients and have shown excellent safety results. The protocols in these studies allow for the titration of the sedative agent by a registered nurse, although a physician was at the bedside, performing the procedure. This is different from our setting, in which the nurses performed the sedation independently, often without a physician or anesthetist in the
hospital during the sedation. Each sedation in our study involved 2 operators because the nurse who performed the sedation was not allowed to be the primary provider performing the procedure.

In high-income countries, patients who are administered ketamine in emergency settings are often monitored by nurses while the physician completes the procedure;11 this practice is supported by the latest clinical practice guidelines.12 Although other investigators have reported on fully trained nurse practitioner use of sedative agents in the ED in resource-rich settings, this study is the first to report on ketamine use by nurses in resource-limited settings.13 Our study describes the outcomes of sedations performed by nurses who were simultaneously enrolled in a training program in emergency care in a resource-limited setting. The goal of this program is to train them to render a diagnoses for patients and assess and treat them independently. Similar to that in studies in more resource-rich settings, overall sedation by nurses in our study was safe, with no major adverse events occurring among the 191 closely monitored sedations.

Although ketamine has an excellent safety profile, it can produce serious adverse events, including laryngospasm and apnea. The overall adverse event rate in our database was 18.3%. All adverse events were minor. In the literature from resource-rich settings, the adverse event rates reported with ketamine vary, likely because different definitions of “adverse event” are used.4 Studies differ in what are considered adverse events, as well as what thresholds are used to define a given adverse event, which makes comparisons between studies more challenging.5,14-17

The overall adverse event rate in our study was similar to that reported elsewhere in the literature for ketamine. We had relatively fewer episodes of emergence reactions and vomiting and relatively more episodes of hypoxia.14-17 The hypoxia issue is addressed below, but we suspect that differences in reported adverse event rates are due more to methodology than to any inherent risk associated with ketamine use in rural Ugandan district hospitals compared with other settings. In a recent large meta-analysis, Green et al reported a 3.9% incidence of airway and respiratory adverse events, whereas in our series there was a 11.9% rate of respiratory and airway (ie, hypoxia and hypersalivation) adverse events.15 However, in a series by Roback et al, a 6% to 10% airway adverse event rate with ketamine and ketamine with midazolam was reported, which more closely approximates the rate in our study.17 In an audit of 200 consecutive ketamine sedations, Gloor et al reported a 12.5% incidence of apnea, a 10.5% incidence of hypoxia (oxygen saturation <90%), 3.5% incidence of hypersalivation, and 1.5% incidence of laryngospasm when ketamine was administered with diazepam by anesthesiologists.16 All of our respiratory adverse events were episodes of hypoxia and hypersalivation. No patient in our series needed bag-valve-mask ventilation or experienced laryngospasm.

There are several possible reasons for the increased rate of hypoxia in our series. Karoli Lwanga Hospital is at elevation (approximately 5,000 feet above sea level), so the partial pressure of oxygen is lower, leaving less oxygen reserve in the lungs to protect against apnea than would be present at a lower elevation. This was partially offset by the fact that 84% of patients received oxygen through a nasal cannula during the sedation and 80% had a presedation saturation of 95% or greater without oxygen. Additionally, our sedations tended to be longer (mean 20 minutes; range 2 to 195 minutes) than those reported in much of the emergency medicine literature, with higher total ketamine doses administered. Longer duration of sedation has been established as a risk factor for desaturation during ketamine sedation.15 It is possible that with more extensive experience using ketamine by the staff in our program, the respiratory adverse event rate will approach that reported by Green et al.15 For example, there was an episode of desaturation below 90% in our series, in which the nurse administering the ketamine did not reposition the airway or increase oxygen delivery. The nadir oxygen saturation was 87% in this case, and the episode lasted 17 seconds. The research assistant observed that the nurse recognized the desaturation and monitored the patient closely, but it is unclear why she did not perform an intervention. Further training and experience will likely reduce such cognitive errors. Overall, however, the nurses clearly demonstrated ability to recognize and manage adverse events and perform sedations of relatively long duration safely.

Another clinically relevant finding in our study was the overall success rate of “adequate” sedation, evidenced by the procedural success rate of 99% and the high level of satisfaction the practitioners had with the level of sedation they achieved. Although we questioned the nurse performing the sedation and not the nurse performing the procedure about his or her satisfaction with the sedation, all of the nurse staff members were credentialed to perform the same procedures, and the assignment of procedure or sedation roles was often arbitrary. Thus, the nurse performing the sedation was qualified to comment on the adequacy of sedation for the particular procedure being performed.

Finally, patient satisfaction with ketamine was high. This was likely multifactorial (eg, related to patients’ receiving any sedation compared with the frequent baseline of no pain relief) and not solely dependent on ketamine. An additional factor was likely the high level of attention paid to patient comfort during procedures. In our emergency training program, there is an emphasis placed on pain relief and patient comfort. It is possible that there was more attention to pain control in this ED setting than in other settings in which these patients receive care, which may have
contributed to the high rate of patient satisfaction with the sedation.

In conclusion, after a brief training program, nurse-administered ketamine sedation in resource-limited settings appears to be both safe and effective. There were no major adverse events in our database, and the success rate of the procedures was high. Implementation of this program has allowed greater access to analgesia and sedation during painful procedures at Karoli Lwanga Hospital.

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**Author contributions:** MB wrote the article. MB, HH, SWN, and SC were responsible for the sedation curriculum. MB, HH, BD, SWN, and SC were responsible for the overall emergency care training curriculum. MB, KN, HH, SWN, and SC designed the quality assurance database. KN, HH, BB, SWN, SC, FK, AN, AA, and ST edited the article. KN oversaw data collection and deidentified the database. FK participated in the emergency care training program and performed ongoing sedation training. AN assisted with data collection. AA and ST were responsible for data analysis. MB takes responsibility for the paper as a whole.

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